A Study on Eyes Tracking Method using Analysis of Electrooculogram Signals

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Abstract

Gaze estimation has been an active research and important technique for seriously physically handicapped person to communicate. In this paper, we proposed eye tracking method using electrooculogram signals which is small-burden. However, there is a problem that the resolution is not so high. Our experiments were conducted to investigate the EOG component strongly correlated with changes in eye movements. The experiment result shows the possibility of eyes tracking method using the analysis of electrooculogram signals.

Keywords: Gaze estimation , Electrooculogram Signal.

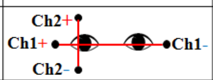
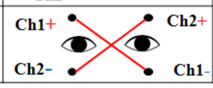
1. Introduction

Gaze estimation has been an active research in the past years and gaze estimation is an important technique for seriously physically handicapped person who cannot move their body to communicate. In this paper, we proposed eye tracking method using electrooculogram (EOG) signals which is widely applied in medical field because of the merit that proposed method have low burden of the patients. In eyes movements, a potential across the cornea and retina exists, and it is the source of EOG. The eyeball can be modeled by a dipole. There are several EOG-based Human-Computer Interface [1] [2][3] studies in literature. Investigating possibility of usage of the EOG for human-computer interface, a relationship between gaze angle and the EOG is determined. However, in-depth studies evoked that slow changing baseline drift is the difficult point to estimate in continuous EOG signals and this drift only appears in DC signals in the circuit. We have already developed EOG system has the center parameter update technique which reduces baseline drift by segmentation of the signal [2]. Our proposed system [2][3] is possible to improve the communication abilities of those patients who can move their neck or/and eye, though there is the problem not to be so high in resolution.

Table.1 shows the characteristic of the proposed method and conventional method. In previous studies[4][5] the positions of the electrodes were set as plus-channels same with direction of the eye movements. The horizontal channel was in charge of horizontal EOG signals and the vertical channel was in charge of vertical EOG signals. The mainstream of eye movement classification is 4 patterns or 8 patterns using an alternating current (AC) signals conventionally.

We proposed the cross-channel method in order to improve the accuracy of the EOG signals. Our proposed technique classified in 4 patterns using AC and DC signals and this method is able to put the electrodes in place far from the eyeballs (Table.1). The proposed technique can say that wearability is good better than conventional method.

Table.1. Characteristic of the proposed method

	Positions of the Electrodes	Performance	Wearability
Conventional Method		○	△
Proposed Cross-channel Method		○	○

We had already developed eyes input application for desktop PC with high accuracy gaze estimation[3].

Furthermore, we carried out the large space experiments (the range is -60degrees to 60degrees) and estimate the gaze by the multiple regression analysis using the DC integral value [6]. Although the regression analysis results are good results, the narrower range was better. In this paper, we analyzed DC, AC, DC difference value, DC integral value for regression analysis and we also checked if the accuracy was improved than previous studies [3]. Moreover, we considered the limiting angle of gaze estimation in a wide space ranging from -90 degrees to 90 degrees.

2. Measurement System using EOG Signals

In this section, cross-channel EOG measurement system design is shown [3]. Fig.1 shows the formal scheme for the acquisition and analysis of the EOG signal for the control organization and flow of information through the system. Our proposal system is based on the five features, 1) Amplifier, 2) Low pass filter for channel 1 and 2, 3) High pass filter for channel 3 and 4, 4) A/D-convertor, and 5) PC. Our system consists of five electrodes, an A/D-convertor, a personal computer, and a monitor. In order to effectively filter functions, channel 3 (and channel 4) is used two amplifiers. The horizontal signals and the vertical signals could be recorded by both channels at the same time which is much easier to analyze data using double signals.

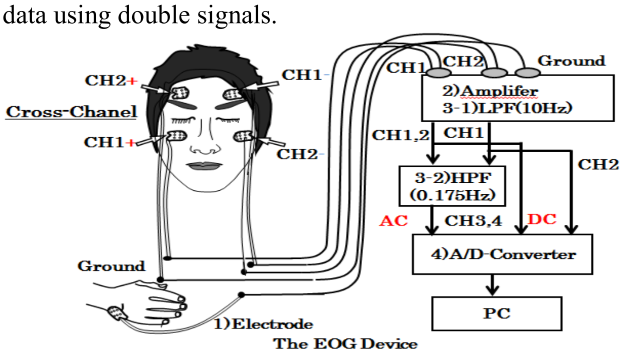


Fig.1 EOG measurement system

3. Method

In this study, we carried out the experiments by our proposal EOG system to make a study the calculation method of the EOG element with strong correlation for the change of the eyeball movements.

3.1. *Experiment environment*

The experiments were designed in order to confirm the effectiveness of the proposal system. Experiment condition is Fig.2 and three healthy subjects participated in this study. We ask the subjects to focus at these targets by moving the eye only as the sequence as 0, -30, 0, -60, 0, -90, 0, 30, 0, 60, 0, 90 degree. Time zoom for watching each target was set as 1 second and repeated 10 times.

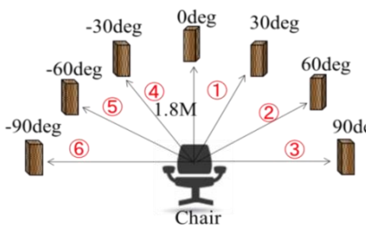


Fig.2 Experiment Environment

3.2. Extraction method of feature value

We carried out the experiments to make a study the calculation method of the EOG element with strong correlation for the change of the eyeball movements. The feature values are (1) AC, (2) DC, (3) DC-Difference value, (4) DC-Integral value.

- Feature value of AC

  The feature value of AC was assumed to be the maximum value when the AC is more than the threshold in the right direction and the minimum value when the less than the threshold in the left direction (Fig.3 (a)).
- Feature value of DC, DC Difference Value

  The feature value of DC is the maximum value and the minimum value (Fig.3(b)), however it is necessary to take the difference with a baseline DC value and the DC value because drift occurs as for the DC signals. The changing baseline drift makes difficult to estimate the EOG signals. The baseline is shown by the dashed line in Fig.3(b). DC difference value$\left(D_{dif}\right)$ is express by Eq.(1) and the maximum value D^R_{max}, D^L_{max} is as below (Eq.(2), Eq.(3)). When D_{dif} exceeds a certain threshold value, D^R_{max} and D^L_{max} is taken as the maximum value.

$$D_{dif}(i) = D(i) - D_{base} \quad (1)$$

$$if: D_{dif}(i) > Th$$

$$D^R_{max} = maxD_{dif}(i) \; : D_{dif}(i) is\ EOG\ active\ on\ Right\ Direction \quad (2)$$

$$D^L_{max} = minD_{dif}(i) : D_{dif}(i) is\ EOG\ active\ on\ Left\ Direction \quad (3)$$

$$i: the\ number\ of\ raw\ EOG\ data$$

- Feature value of DC Integral Value.

  DC integral value is the linear weighted sum of the DC difference value subtracting baseline and we obtain the value of the eyes position. By taking the maximum value of the DC integral (X^R_{max}, X^L_{max}) is stable when feature can be expressed. The dashed line is the value of DC, and solid line is the sum of the value of DC (Fig.3 (c)). Eq. (4),(5),(6) show DC integral value. The maximum value X^R_{max}, X^L_{max} is as below.

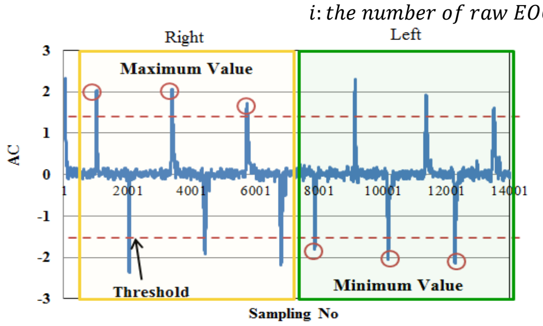
$$X(i) = \sum_{i=1}^{N} D_{dif}(i) : N = 200 \quad (4)$$

$$X^R_{max} = max\,X(i) : X(i)s\ EOG\ active\ of\ Right\ direction \quad (5)$$

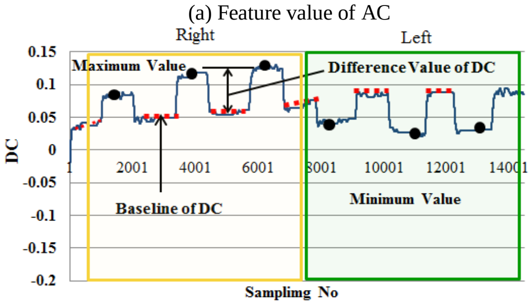
$$X^L_{max} = min\,X(i) : X(i) is\ EOG\ active\ of\ Left\ direction \quad (6)$$

$$(i = 0,1,2 \ldots N)$$

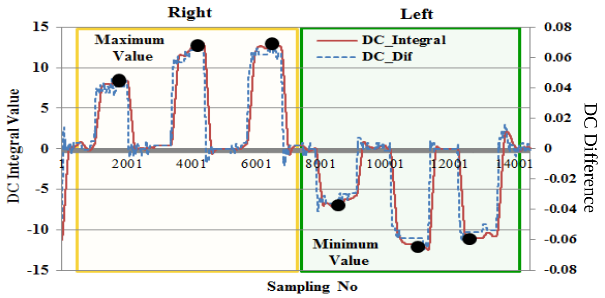
i: *the number of raw EOG data*



(a) Feature value of AC



(b) Feature value of DC



(c) Feature value of DC integral Value

Fig. 3. Feature value of proposed method

3.3. *Data Analysis*

In our previous studies [3][6], we have carried out the gaze estimation in the range from -60 degrees to 60 degrees. Therefore, in this paper we have estimated the gaze from -90 degrees to 90 degrees.

In order to confirm the accuracy of EOG system, we try regression analysis. We tried two types of regression analysis. First is the multiple regression analysis as linear regression analysis, second is the logistic regression analysis as non-linear regression analysis.

DC was known to have a linear relation to the eyeball angle, so we performed a multiple regression analysis with the next explanation variable : AC, DC, DC integral, DC difference. However, most previous works were carried out the experiments in the small space such as desktop PC [3]. We assumed that DC elements might not be linear shape characteristics in the large space such as this experiment and performed a nonlinearity logistic-regression analysis with an explanation variable same as a multiple regression analysis. We computed the predicted gaze degree by two type of regression analysis for each subject. We compared the explanation variables which is the most suitable variable using EOG in large space.

4. Experimental Results

In this section, we describe the gaze estimation results of -30degrees, -60degrees, -90degrees 30degrees, 60degrees and 90degrees. In this experiment, the proposed analysis method is the major analysis items of the angle of the target which subjects look to clarify the correlation between. The result of calculating the respective correlation coefficients R^2 are shown in Table 2. All the result over $R^2 > 0.83$, that shows the correlation of all analyses. In addition, DC integral value is higher in the results.

Table.2. The Correlation Coefficient of the multiple regression

	AC	DC Difference	DC Integral
SubjectA	0.8356	0.7906	**0.9257**
SubjectB	0.8440	0.9080	**0.9222**
SubjectC	0.8452	0.8451	**0.9064**

From the result of the multiple regression analysis, we conducted the logistic-regression analysis about DC integral value. In addition, we calculated the average error between the predicted value and the true value obtained by multiple regression analysis, logistic regression analysis (Fig.4).

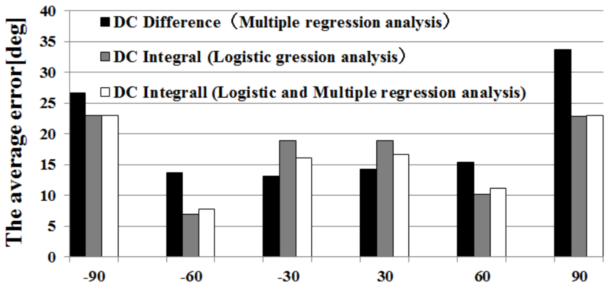


Fig. 4. The average error

Fig.4 shows that 60 degrees and -60 degrees were the small average error among each angle at left and right direction. And the gaze estimation by nonlinear analysis is better for angles bigger than 60degrees or less than -60degrees. The results of all data from -90 degrees to 90 degrees, the multiple regression analysis were 19.5 and logistic regression analysis was 16.2. Fig 4 shows that whether the relation of DC element and eyeball angle is linear or not depends on eyeball angle. Therefore, we established the boundary line (DC Integral Value:±15V) and separated a linear/nonlinearity and combined the results of the logistic-regression analysis and the multiple regression analysis (Fig.4 and Fig.5).

The eyeball angle of the 60degrees and -60 degrees are most easy to judge by EOG and the success rate is 88% without considering the individual difference of 3 subjects. At 90 degrees and -90 degrees, the judgment is difficult because individual is wide and the value of EOG tends to be saturated. About 30 degrees, -30 degrees, two of three people were 60% of success rates. One of the causes having low success rate is the influence of the individual differences. Based on 60 degrees, our analysis method can be classified as pattern 1) center (Fig.5), pattern 2) center to 60 degrees range, pattern 3) 60 degree over, pattern 4) center to -60 degree range and pattern 5) -60 degree less. Our analysis method can be said that 5 patterns are the appropriate number of judgment patterns.

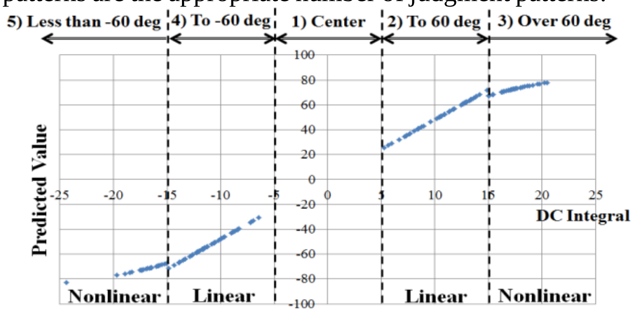


Fig. 5. The relation between the predicted value and the DC Integral value

5. Conclusion

In this paper, we conducted experiments to examine EOG elements that have a strong correlation with eye movement changes and from the experiments, we found that the following three points in this study.

1) From Table 2, DC Integral value is the most effective EOG signals to gaze estimate.
2) In the gaze movement in large space, the right and left 60 degrees is the best success rate.
3) DC integration is possible to classify 5 patterns by combining linear and nonlinear regression analysis results.

When gaze estimation is performed in a large space, we understood that the gaze estimation of 60 degrees on the left and right is the most stable. Therefore, by arranging the object at 60 degrees, our system is possible to perform input of 5 patterns with line of sight. By setting the lower limit of 60 degrees on each side, it is easier to use with success rate of Subject A: 85%, Subject B: 100%, Subject C: 79% without calibration. Therefore, the gaze estimation system of this study is a possibility to use as the application of the communication tool of patients with brain disease.

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